GAṆANAM (गणनम्)

HIGH PERFORMANCE *COMPUTING* NEWSLETTER

INSTITUTE FOR PLASMA RESEARCH, INDIA

Numerical Validation of Magnetoplasmons in a Rotating Dusty Plasma Experiment
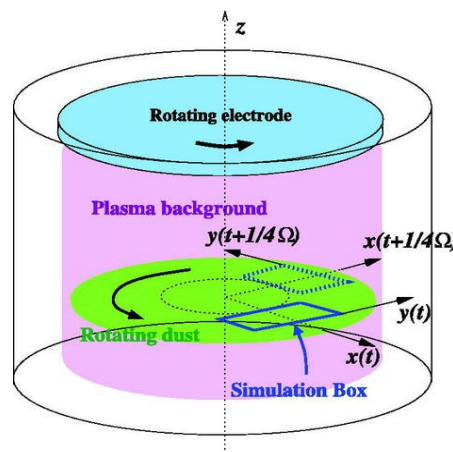
Prince Kumar (PhD Student, Basic Theory and Simulation Division, IPR)
Email: prince.kumar@ipr.res.in

Figure 1: Schematic of the setup of dusty plasma rotating with frequency induced by a rotating electrode. The rectangular simulation zone located in the frame corotating with the dust is drawn at time t (solid line) and at quarter of the rotation period after time t (dotted line) in the laboratory frame.
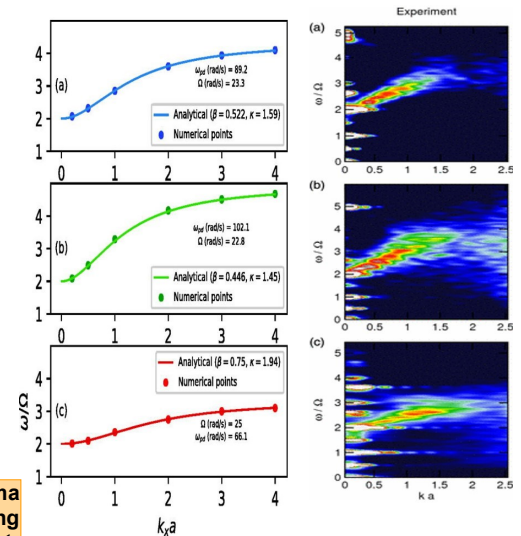

Figure 2: Simulation and Experimental longitudinal dispersion relations [3] of a weakly and strongly coupled rotating dusty plasma, respectively, with different rotational frequency.

Strongly coupled systems share their dynamical regime with many natural systems [1], such as neutron stars, white dwarf, etc. It has been predicted from several theoretical and simulation results that a strong magnetic field drastically alters the spectral and transport properties of the strongly coupled systems. Dusty plasma may be an ideal candidate to verify these predictions from an experiment on very accessible Spatio-temporal scales [1]. But, due to its small charge-to-mass ratio, a tremendous amount of magnetic field, practically unachievable in a Lab experiment, is required to magnetize the dust component. To the mutual effects of strong coupling and a strong magnetic field in a Laboratory dusty plasma experiment, an alternative approach has been proposed and demonstrated in recent experiments [2,3] which may allow us to verify these predictions. The key idea is to put dust particles into the rotation via various mechanisms, such as by rotating electrodes. In the rotating frame, the dust particles experience the Coriolis force that is equivalent to the Lorentz force of a magnetic field. These existing studies have estimated the effects of a magnetic field equivalent of 10^4 Tesla and show the first experimental observation of the magnetoplasmon modes and their dispersion in a strongly coupled plasma.

To get deep insights into such systems, collective excitations of a 2D rotating dust flow, drawn schematically in Figure 1, are analyzed under the quasi-localized charge approximation (QLCA) framework for strongly coupled systems by explicitly accounting for dust rotation in the analysis. We have obtained magnetoplasmon-equivalent mode dispersion from both strong and weak coupling limit of the QLCA theory, by perturbing any general rotating equilibria such as shown in Figure 1 [4]. The observed close correspondence between the strong to the weak coupling limit of the theory increases significantly at the higher rotating frequency [5].

To validate these predictions, ***a 2-dimensional serial pseudo-spectral code has been developed to solve the model equations representing a compressible rotating weakly coupled dust flow which is subjected to the Coriolis force*** [5]. By considering a set of parameters used in a strongly coupled rotating dusty plasma experiment, we drive a dispersion relation showing a close correspondence with the experiment results at a higher rotational frequency as predicted in the QLCA theory. Simulations have been performed first on PC using the FFTW library to solve the space derivatives in spectral space. The same code was ported successfully on ANTYA to get the simulations outputs faster. The spatial and temporal discretization's are done using the k and t variable, respectively, and satisfy the Courant-Friedrichs-Lewy (CFL) condition. The Adam-bashforth method has been used for time-stepping. For all the results obtained in the numerical analysis, we chose a grid of size $N_x \times N_y = 256 \times 256$ and the time step value $\delta t = 10^{-3} \omega_{pd}^{-1}$ (dust frequency). The amplitude of the perturbation in velocity components and density are all chosen to be equal, with values $\delta u_d / (a \omega_{pd}) = \delta n_d/(Z_d n_{d0}) = 0.001$ where a is lattice constant, u_d is dust velocity, n_d is dust density

> *"The developed pseudo-spectral code will enable us to investigate linear and nonlinear effects in a strongly coupled rotating dusty plasma which may be applicable in a strongly coupled magnetized plasma."*

and Z_d is charge on dust species. The set of parameters are chosen from the experiment [3] for obtaining magnetoplasmon modes and their dispersion relations. Wave-like solutions are obtained from numerical evolution of the dust parameter perturbations, with periodic boundary conditions implemented along both x-and y-directions. Numerical dispersion relations for a different set of parameters are presented in Figure 2. It has been shown that the experimental and numerical dispersion relation matches quantitatively only at a higher rotational frequency (Ω) which confirmed our theoretical predicted results [5] (saturation in the frequency around 3Ω). These simulation results predict that strong coupling effects compete with strong magnetic field effects in the rotating dusty plasma.

References:

1. Bonitz, M., et al. "Magnetized strongly coupled plasmas and how to realize them in a dusty plasma setup." *Plasma Sources Science and Technology* 22.1 (2012): 015007. and Aleksandr Y Potekhin, The physics of neutron stars.
2. H. Kählert, J. Carstensen, M. Bonitz, H. Löwen, F. Greiner, and A. Piel, Phys. Rev. Lett. 109, 155003 (2012). https://doi.org/10.1103/PhysRevLett.109.155003
3. P. Hartmann, Z. Donkó, T. Ott, H. Kählert, and M. Bonitz, Phys. Rev. Lett. 111, 155002 (2013). https://doi.org/10.1103/PhysRevLett.111.155002
4. P. Kumar and D. Sharma, Phys. Plasmas 27, 063703 (2020). https://doi.org/10.1063/5.0010850.
5. Kumar, Prince, and Devendra Sharma. "Collective excitations of rotating dusty plasma under quasi-localized charge approximation of strongly coupled systems." *Physics of Plasmas* 28.8 (2021): 083704.

Running MATLAB Programs on ANTYA
Part-1: Running MATLAB in Interactive Mode

This HPC article series focusses on the execution of *MATLAB - a high-level language and interactive environment for numerical computation, visualization and programming* on ANTYA HPC Cluster. MATLAB is a commercially licensed software which is installed on ANTYA as a module. The version available on ANTYA is **R2016a**. Users have access to a limited number of licenses both for the base MATLAB software as well as some specialized toolboxes. Users are encouraged to try out the open source alternatives of MATLAB like GNU Octave, Python etc. This series has been divided into 6 parts, covering 1 part in every issue, starting from part-1 in the current issue:

♦ **Part-1: Running MATLAB as an Interactive Job**

This will cover how you can run MATLAB on ANTYA similar to how you run on your local PC/Workstation/Laptop. ANTYA has a dedicated visualization node for running MATLAB short jobs.

♦ **Part-2: Running MATLAB in Batch Mode (Non-interactive)**

For the long production runs, it is recommended that MATLAB should be run on the compute nodes of ANTYA using the jobscript. This part will demonstrate how MATLAB batch jobs can be submitted.

♦ **Part-3: How to Access MATLAB via Your Local Web Browser**

For the users who are new to high-performance computing and Linux environment, the simplest way to use MATLAB on ANTYA is through the web browser. This part will show how your web browser can be used for MATLAB runs.

♦ **Part-4: Using the MATLAB Compiler for Compiling Your Code**

Here it will be shown how you can use the MATLAB compiler to compile your MATLAB codes. While running the job using the MATLAB compiled executable, there is an added advantage of no MATLAB license restriction.

♦ **Part-5: Running MATLAB on Multiple Cores with the Parallel Computing Toolbox**

This will cover how you can launch MATLAB on multiple cores in parallel and run your code faster.

♦ **Part-6: How to Check MATLAB Licenses Availability Including Toolboxes**

The last article of MATLAB series will cover how as a user you can check the availability of MATLAB licenses and run your MATLAB jobs accordingly.

Part-1: Running MATLAB as an Interactive Job

Option-1 on Visualization Node: You can work with MATLAB interactively on visualization node of ANTYA for light workload (< 20 GB RAM usage) and short walltime (max. 30 minutes) problems.

 # First login to the cluster with X11 forwarding option. Then from either login1 or login2 go to the visualization.
```
[user@login1 ~]$ ssh -X visualization
```

 # Load the MATLAB module on visualization node
```
[user@login1 ~]$ module load MATLAB/2016a
```

 # Run the MATLAB command to open in the MATLAB GUI
```
[user@login1 ~]$ matlab
```

1. New Packages/Applications Installed

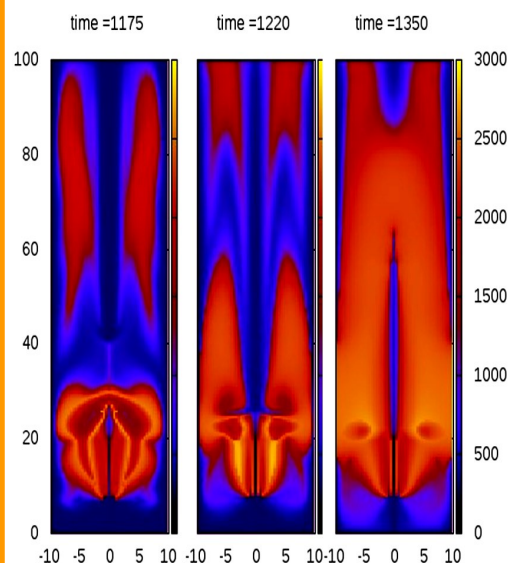⇒ **LAMMPS latest version GPU Module now available**

The latest available package can be accessed from **lammps-2020/ gpu/29SEPT2021_updated** module.

⇒ **OpenFOAM latest version Module now available**

The latest available package can be accessed from **OpenFOAM-v2106** module.

HPC PICTURE OF THE MONTH

Evolution of Diesel Cracking Flame using Plasma Arc

Pic Credit: **Sunil Bassi**

The figure shows early stages of flame development process shown by temperature profiles in a Plasma Fuel System chamber, where electric arc is used to burn fuel/air mixtures at different times of its evolution.

Data is taken from in-house modified code written in FORTRAN and plotted with gnuplot on ANTYA.

TIP OF THE MONTH

Did you know that without shared module which is automatically loaded in your environment, no other modules would be visible.

```
[user@login1 ~]$ module list
Currently Loaded Modulefiles:
      1) shared
```

(HPC Article Continues…) Part-1: Running MATLAB as an Interactive Job

Option-2 on Compute Node: In the option-1, we saw how you can use visualization node for the MATLAB interactive session. However, if you need to use MATLAB interactively for longer duration as well as for heavy workload, the use of visualization node is not recommended because of parallel workloads from several other HPC Users. **You can work with MATLAB interactively on compute node of ANTYA for heavy workload (multicore) and large walltime (< 6 hours) problems**.

```
# Submit an interactive job. Select the resources as per your job requirement while submitting the job. Please refer for more info https://www.ipr.res.in/ANTYA/Gananam_HPCNewsletter_IPR_Issue1_Dec2020.pdf.
[user@login1 ~]$ qsub -I -X -q serialq -l select=1:ncpus=8,
walltime=04:00:00


# Go to your working and Load the MATLAB module on compute node (here job went to hmcn02 compute node, it could be different in your case).
[user@hmcn02 pbs.XXXXX.ANTYA.x8z]$ cd /your/workdir
[user@hmcn02 ~]$ module load MATLAB/2016a

# Run the MATLAB command to open in the MATLAB GUI
[user@login1 ~]$ matlab
```

Important Caveat: The use of login nodes for MATLAB interactive sessions is not allowed. If Users running jobs are found on any of the login nodes, the jobs will be terminated to maintain the health of the login nodes for seamless HPC Users' experience.

Other Recent Work on HPC (Available in IPR Library)

Why quasi-longitudinality is the order of the day in electromagnetic turbulence?	**DEVENDRA SHARMA**
Physics of surface waves: A kinetic approach	**B.J. SAIKIA**
Development of prototype pulse-tube refrigerator for typical cry-opumps used in fusion devices	**ROHAN DUTTA**
Quasi-longitudinal propagation of nonlinear whistlers with steep electrostatic fluctuations	**GAYATRI B BARSAGADE**
Computational studies of current driven instabilities in a tokamak plasma	**JERVIS RITESH MENDONCA**
Laser cluster interaction in ambient magnetic field: accelerating electrons in two stages	**KALYANI SWAIN**
Effect of interparticle interaction on motility induced phase separation of self-propelled inertial disks	**SOUMEN DE KARMAKAR**
Towards a 3D Quiescent Nonneutral Plasma State in Small Aspect Ratio Torus - A Particle-In-Cell Simulation Study	**SWAPNALI KHAMARU**
Droplet Motion on Wettability Gradient Surface	**VISHAKHA BAGHEL**
Installation and Performances of temperature sensors during cryogenic testing of Magnet Test Facility	**PIYUSH . RAJ**

ANTYA HPC USERS' STATISTICS—
DECEMBER

- **Total Successful Jobs — 2826**
- **Top Users (Cumulative Resources):**
  ⇒ **CPU Cores — Suruj Kalita**
  ⇒ **GPU Cards — Suruj Kalita**
  ⇒ **Walltime — Swapnali Khamaru**
  ⇒ **Jobs — Swapnali Khamaru**

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